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Oriented Movement of the Boll Weevil in Response to Trap Crop Plantings, Foliage Color and Sex Pheromone.

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ORIENTED MOVEMENT OF THE BOLL WEEVIL IN RESPONSE TO TRAP CROP PLANTINGS, FOLIAGE COLOR AND SEX PHEROMONE

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ABSTRACT

Objectives of this research were to obtain ecological data about the boll weevil, *Anthonomus grandis* Boheman, relative to dispersal of overwintered populations in response to selected stimuli and to utilize these data in control programs.

A three-year study of the boll weevil dispersing from hibernation sites was made in northeast Louisiana. Data from these studies indicated that boll weevils tend to congregate in areas of older, more mature cotton upon emerging from winter quarters, especially if such areas are located adjacent to hibernation sites.

Overwintered boll weevils concentrated in early planted border rows of cotton if the differential in planting dates was sufficient to give a distinct difference in size of plants. Insecticides applied to areas where boll weevils were congregated caused a retardation in buildup of populations in adjacent areas, thereby delaying the date at which overall insecticide treatment had to be initiated.

Studies conducted during 1965 and 1966 showed that the boll weevil exhibited a distinct nonpreference for cotton possessing genetic characters for red foliage. Where fields of cotton possessing red foliage were bordered by narrow strips of cotton

possessing green foliage, boll weevils tended to congregate in the border strips upon entering the fields. Where such concentrations occurred, subsequent applications of insecticides reduced boll weevil numbers and thus delayed population buildup in the remainder of the field.

Studies were conducted on the behavior of boll weevils in the field in response to the sex pheromone. Data from these studies indicated that both the boll weevil and the thurberia weevil, *Anthonomus grandis thurberiae* Pierce, emit some sort of sex attractant, or assembling scent, to which boll weevils respond under certain conditions in the field. Caged males were more attractive than caged females. Both males and females were attracted to caged males. Response was obtained only during the early part of the cotton growing season at which time overwintering boll weevils were entering the cotton fields.

INTRODUCTION

The control of insect pests achieved with chlorinated hydrocarbon insecticides since World War II has been so dramatic that many less spectacular methods of insect suppresssion have been replaced and their value forgotten. With the gradual development of previously unrecognized problems associated with insecticide-based control programs the trend has reversed. Insecticide resistance, residues in plant and animal tissues, and possible undesirable side-effects on populations of nontarget species by present programs has necessitated the re-evaluation of alternate means of suppressing insect pests. Concentrated effort is now being directed at possible ways of reducing pest populations by using biological and cultural control techniques. Emphasis is placed on integrated control programs where alternate means are used to reduce the amount of insecticide necessary to maintain insect populations below economic injury thresholds.

The purpose of this study was to evaluate the feasibility of using cultural methods to supplement chemical methods in controlling the boll weevil. An effective control method requiring fewer applications of insecticides would be preferable to existing programs.

The incorporation of trap crop plantings in boll weevil control programs was evaluated. The degree of resistance (non-preference) exhibited to the boll weevil by a selection from Stoneville 7 cotton possessing red foliage was studied and tests were conducted utilizing this selection in a boll weevil control program. Additional studies were conducted on the behavior of boll weevils in the field in response to the sex pheromone.

SECTION I

TRAP CROP PLANTINGS FOR BOLL WEEVIL CONTROL

The use of trap plantings to concentrate populations of insect pests and thereby facilitate their destruction has been utilized in insect control for many years. The present studies were primarily concerned with determining whether trap plantings of cotton could be used effectively in boll weevil, *Anthonomus grandis* Boheman, control programs.

Literature Review

A trap crop is considered by Johansen (Pfadt, 1962) to be a small planting of a susceptible or preferred crop which is established near a major crop to act as a "trap" for the particular insect concerned.

The preferred host serves as a trap crop to which the pest is attracted, and while this attraction continues the major crop will be relatively free of infestation by the pest concerned. The trap crop plants and the attracted insects are usually treated with an insecticide to eliminate the pest. In some cases the pest may be destroyed by mechanical means such as crop destruction. If not properly handled the trap crop may develop into a breeding center for the pest and ultimately serve as a source of infestation for the main crop. To prevent this the trap crop must be destroyed at the proper time or treated with an effective insecticide when the infestation approaches maximum or before the beginning of "migration" of the pest to the major crop (Isely, 1957).

A notable example of the use of a trap crop to alleviate insect damage to cotton is the use of corn to concentrate the cotton bollworm, _Heliothis zea_ (Boddie), thus reducing damage to cotton. This was recommended as a means of control of the bollworm over the entire world where corn and cotton were grown (Lincoln and Isely, 1947; Isely, 1957).

Trap plantings of cotton have been used for many years in studies of hibernation, survival and emergence of the boll weevil. Many of these studies involved small plantings of cotton adjacent to boll weevil overwintering sites (Fenton and Dunnam, 1927; Fenton and Dunnam, 1928; Bondy and Rainwater, 1942; and Fife _et al._, 1950). These "trap" plots were planted considerably earlier than the remainder of the area in order to concentrate populations of overwintered weevils.

Other investigators making similar studies used greenhouse grown cotton plants (Grossman and Calhoun, 1931; Gaines, 1959; Smith _et al._, 1965). These plants could be transferred to fields prior to the time that soil temperatures would be conducive to seed germination.

These tests substantiated the idea that boll weevils would concentrate in older cotton especially if it were located adjacent to overwintering sites.

Additional studies (Ballard and Simpson, 1925; and Everett, personal communication, 1965) concerning distribution of the boll weevil in relation to plant growth showed that a greater number of overwintered weevils can be expected on taller cotton than on shorter plants in the same field. This was found to be true even when randomization eliminated the variable due to hibernation sites.

Recent investigations have shown that emerging overwintered weevils are able to find small isolated groups of squaring cotton plants even when removed considerable distances from overwintering sites (Beckman and Morgan, 1960; Parencia *et al.*, 1964; and Mistric and Mitchell, 1966).

The idea of using trap plantings to facilitate boll weevil control was advanced soon after entry of the boll weevil into the United States. Early researchers were not in agreement as to the merits of this approach.

Howard (1896) referred to trapping late weevils in the fall and overwintered weevils in the spring. Mally (1901) recommended the destruction of all but a few rows of cotton following harvest; these were to be poisoned frequently or grazed down. Hunter (1917) stated that while some hope of control of the boll weevil through trapping the overwintered weevils had been advanced, this method was not very promising. Hunter and Coad (1923) reported: "The idea of attracting weevils to a few early plants or trap rows has frequently been advanced. Practical experience, however, has shown that the only possibility of success in such a procedure lies in the use of entire fields adjoining hibernation quarters, the fields to be poisoned later. The use of only a few rows as a trap crop has been found to be absolutely valueless."

Isely (1924) stated, "In planning dusting operations it should always be recognized that in Arkansas the boll weevil is a local problem and that usually early infestations occur only in a very small part of the cotton producing acreage, as a rule in corners or along margins of fields. No advantage is gained in dusting a whole field because a corner is infested. Furthermore, if energy is dissipated over a large area instead of being concentrated where it is needed, not only is much labor and material wasted, but the work is likely to be inefficient and the whole program a failure."

Spot dusting, to destroy early infestations of weevils or to retard their spread before they began to reproduce was first recommended in Arkansas in 1924. Isely (1926 and 1932) reported that infestations of overwintered weevils could be expected in relatively small areas near situations particularly favorable for hibernation of boll weevils. Spot dusting was reported very successful if the areas of infestation could be located and dusted before the boll weevils began to spread over the entire field. Isely (1926) said, "The most frequent difficulties encountered in dusting to control the cotton boll weevil in Arkansas are in locating early infestations and in making dust applications when they will be most effective."

Isely (1934) suggested that an early cotton variety, particularly if it germinated well and was relatively cold hardy in the seedling stage, could be used as a trap crop in concentrating infestations of overwintered boll weevils, provided that the trap crop was planted somewhat earlier than the main variety. He was also of the opinion that such trap crops were of value only in situations where early infestations of overwintered boll weevils were known to occur every year. Isely also stated that overwintered weevils tended to concentrate in the older cotton causing a sharp difference in the degree of infestation of the trap variety and the main planting. This difference in infestation always justified early poisoning of the trap crop.

Isely in 1950 iterated his belief that trap plantings were a useful tool in the boll weevil control program. He said that while spot dusting had proven successful, the chief obstacle to such a program had been the necessity of careful field observations in order to delimit the areas of the early infestation. To simplify this problem a trap crop of early cotton was used. Since boll weevils tend to concentrate in older cotton, the infestation of overwintered boll weevils could be concentrated in a few rows of cotton, planted early in spots adjacent to sites favorable for boll weevil hibernation. Trap plantings 3 to 30 rows wide, depending upon the size of the field, were utilized. When trap cotton was distinctly earlier than cotton in the remainder of the field there was a concentration of boll weevils in trap rows. Better results were obtained when tests were conducted on light, well-drained soils. Under such conditions the early planted varieties were more vigorous.

OBSERVATIONS OF EARLY-SEASON BOLL WEEVIL POPULATION BUILD-UP IN COTTON FIELDS

The objective of the preliminary observations was to verify that overwintered boll weevils tend to congregate in earlier plantings of cotton if a choice is available.

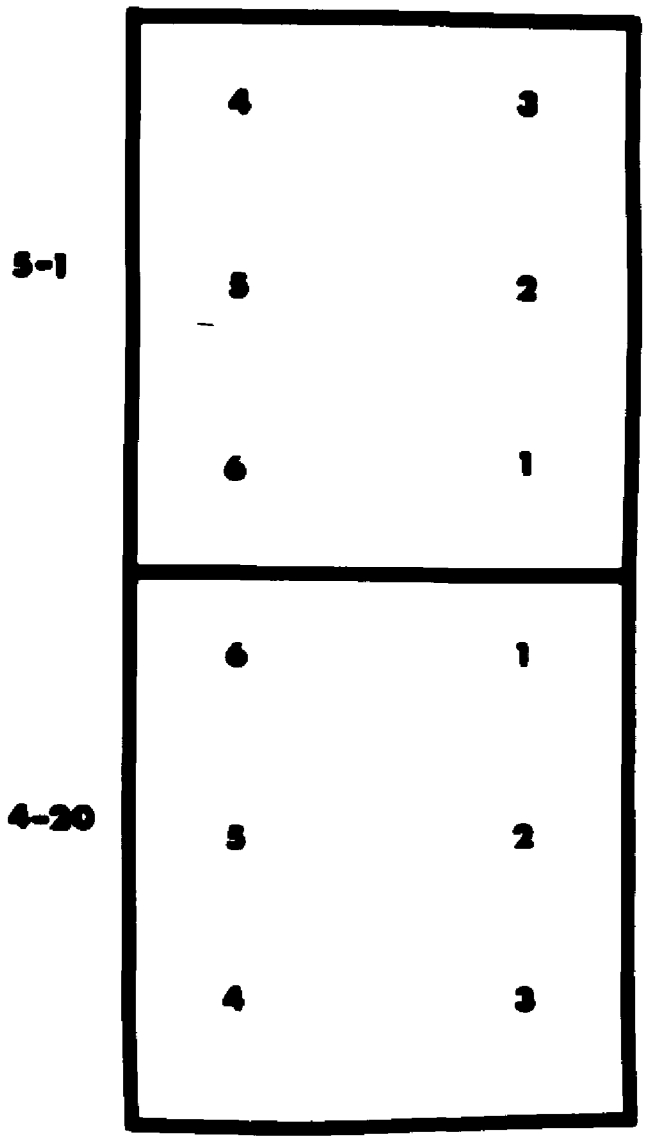
Procedure

In order to determine if overwintered boll weevils actually congregate in older, more mature cotton, weekly observations were made during the early months of the 1964 cotton growing season. The observations were made in cotton fields on two farms in the southern part of Tensas Parish. At each farm adjacent cotton fields, one planted April 20 and the other May 1, were observed.

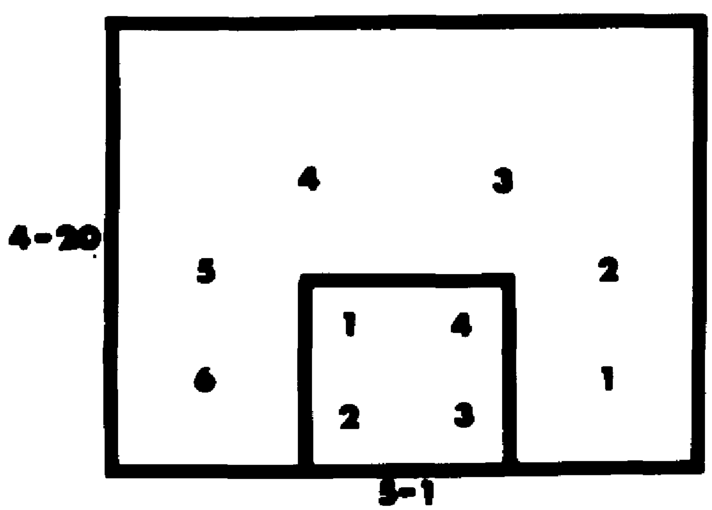
Test 1 involved adjacent 40-acre fields planted to Stoneville 13 (Figure 1). Both fields were located on well-drained, sandy-loam soil, prepared, planted and cultivated in the same manner. Test 2 involved a 5-acre cotton field planted May 1 bordered on 3 sides by cotton planted April 20 (Figure 1). Both fields were planted to Deltapine Smoothleaf and were prepared, planted, and cultivated in a similar manner. However, this test area was located on poorly drained, heavy clay soil.

Prior to square examinations, stand counts were made at both locations to determine whether the number of plants per acre was comparable for the different dates of planting. In test 1 the number of plants per 50 feet of row was determined at eight locations in each test field. In test 2 only 6 samples were taken in each test field.

Figure 1. Diagrams of the fields observed during 1964 showing relative positions, sizes, sample locations, and planting dates.



LOCATION
1



LOCATION
2

At each farm observations were made weekly at designated locations within each test field. Samples were taken in the same approximate locations, but at slightly different sites in order to avoid any adverse effect that weekly handling of the plants might produce. Sampling was done in the same general locations at weekly intervals so that changes in the boll weevil infestation within specific areas could be detected. Sampling points for both areas are shown in Figure 1.

Each sample consisted of the systematic examination of plant fruiting forms on a specified number of row feet. Only the fruiting forms large enough to be infested by the boll weevil were considered. Each sample consisted of 50 row feet initially, but was reduced as the season progressed because of the increased number of fruiting forms. Observations were continued until boll weevil infestations reached a level which justified insecticide application. Samples were projected to the acre basis in order to obtain comparative figures of infestation between the two dates of planting from each location.

Results and Discussion

Preliminary stand counts showed only slight differences in number of plants per 50-foot sample for the 2 dates of planting in each test. In test 1 (Keyes farm) the earlier planted cotton had an average of 145 plants per sample while the later planted had 158 plants. In test 2 (James farm) the figures were 184 and 176 plants per sample, respectively. Since adequate stands were obtained for both dates of planting in each test it was considered that differences in number of fruiting forms observed in weekly samples were due to factors other than difference in plant stands.

Results of weekly sampling in test 1 are presented in Table I. Sampling was started in the early planted field June 8 and in the later planted field June 16, dates corresponding with the onset of squaring in the respective areas. Results from weekly samples projected to a per acre basis show that fruiting trends of the two fields were very similar considering the 10-day difference in planting dates. Boll weevil infestation, presented as the mean of 6 samples in each field, was consistently lower in the later planted field. The infestation in this later field lagged behind the infestation in the earlier planted field by about the same time as the difference in the planting dates of the two. Insecticide treatment was begun in the early planted field July 13 and on the later planted field July 23, therefore, the difference in dates of required insecticide treatment was the same as their difference in planting dates. Data in Table I give no indication that overwintered boll weevils in the area concentrated in the older cotton in preference to the younger. However, individual samples not evident in the mean revealed consistently lower boll weevil infestations in the younger cotton at sampling points 1 and 6. At these points in the field it was indicated by infestation counts that overwintered boll weevils had moved into the adjacent older cotton. On the last sampling date points 1 and 6 showed only 2 percent boll weevil damaged squares

Table I. Comparisons of fruiting and boll weevil infestations in cotton fields of different ages in test 1, Keyes farm, 1964

Planting date	Sampling date	Average number per acre: Squares	Bolls	Weevil damaged squares	Percent weevil damaged squares
4-20	6-8	11,601	0	461	4
	6-16	50,051	0	6,077	12
	6-23	111,601	5,227	6,708	6
	6-29	201,160	15,682	7,144	4
	7-6	292,505	59,242	29,403	10
	7-13	263,974	84,506	44,867	17
5-1	6-16	16,727	0	741	4
	6-23	49,571	0	2,091	4
	6-29	111,688	4,095	2,962	3
	7-6	191,882	18,731	1,307	0.6
	7-13	210,177	44,867	8,930	4
	7-20	216,711	86,031	23,087	11

while points 3 and 4, farthest removed from the older planting had over 40 percent squares damaged. These data indicated that boll weevils moved into the older cotton in preference to the younger where a choice was available, but at points far removed the overwintered boll weevils appeared to have settled in the younger cotton upon emergence from nearby overwintering sites.

Results of weekly sampling in test 2 are presented in Table II. Sampling was initiated in this area on the same dates as in test 1. Data from this location show that while trends in fruiting were similar for the two dates of planting, boll weevil infestation was markedly different. Cotton fruiting forms damaged by feeding and oviposition of overwintered boll weevils constituted 11 percent of the total forms examined on the first sampling date in the earlier planted cotton. The percentage dropped considerably the next sampling date because the plants had begun to fruit heavily. Subsequent samples, however, showed an increase until the fifth week when 24 percent of the squares examined was damaged and insecticide treatment was recommended. The later planted field, however, was characterized by a gradual build-up in boll weevil infestation. The percentage of fruiting forms damaged did not exceed 20 until the seventh week of sampling. At this time treatment was recommended, but from data in Table II it can be seen that the later planted cotton was much nearer maturity than was the earlier planted cotton when treatment was required. At the time treatment was required the later planted area possessed one-third more squares and 5 times as many bolls as did the earlier planted area at a similar

Table II. Comparisons of fruiting and boll weevil infestations in cotton fields of different ages in test 2, James farm, 1964

Planting date	Sampling date	Average number per acre: Squares	Bolls	Weevil damaged squares	Percent weevil damaged squares
4-20	6-8	566	0	87	11
	6-16	6,926	0	87	1
	6-23	29,795	87	2,352	7
	6-29	56,715	958	5,140	9
	7-6	103,074	9,474	24,829	24
5-1	6-16	65	0	0	0
	6-23	2,221	0	0	0
	6-29	22,216	0	275	1
	7-6	58,153	81	980	2
	7-13	66,647	7,187	327	0.5
	7-20	114,999	26,787	7,514	7
	7-27	138,848	45,738	29,730	21

date. The interval between planting dates of the two areas in location 2 was 10 days, while the interval between dates when insecticide treatment was required was 20 days. The 10-day delay of treatment in the later planted field was during a period of intense fruiting that resulted in the large difference in number of fruiting forms present. It is suggested that the 10-day delay in beginning treatment was a result of overwintered boll weevils in the area congregating in the earlier planted cotton in preference to that planted later. This concentration of weevils probably occurred because the earlier planted cotton was situated between boll weevil overwintering sites and the later planted cotton.

Data from weekly observation at the two tests suggest that boll weevils do tend to concentrate in earlier planted cotton, but with much greater frequency when the earlier planted cotton is situated between overwintering sites and the later planted cotton. Also it suggests that insecticide applications might be considerably delayed on the majority of the cotton acreage if overwintered boll weevils could be concentrated along the borders of the fields in early plantings. Once concentrated in the "trap" rows, populations could be reduced by application of insecticide to retard movement into later planting.

TRAP PLANTINGS FOR BOLL WEEVIL CONTROL

In previous studies it had been observed that cotton plants which are taller and which begin forming squares earlier are particularly attractive to boll weevils upon their migration into cotton fields from overwintering sites. With this observation as a basis, the purpose of these tests was to concentrate infestations of hibernated boll weevils into narrow strips of early planted cotton along the sides of fields. When overwintered boll weevils did concentrate in these strips, attempts were made to reduce population numbers and limit movement into the remainder of the field by applying insecticides. The success of this procedure would be evident if the initial treatment date of the main bulk of cotton was delayed resulting in fewer applications of insecticides to complete the cotton growing season.

Procedure

Each test consisted of two similar fields in close proximity planted at the same time or within a few days of each other, and subjected to similar tillage and weed control procedures. Narrow border strips of cotton were planted along the sides of one of the fields 1 to 3 weeks prior to the general planting date of the two fields. These early-planted border rows were to serve as "trap" rows as it was considered that upon moving into this field hibernated boll weevils would prefer the more advanced cotton and would settle in the border rows. The second field, having no early-planted border strips, was designated as a control field.

The cotton variety used throughout these tests was Deltapine Smoothleaf. The cottonseed planted in the border strips were treated with either Thimet® (phorate) at the rate of 0.33 lb/100 lb of seed or Di-syston® (disulfoton) at the rate of 0.50 lb/100 lb of seed. This treatment was done as a preventive measure to insure protection from the tobacco thrips, Frankliniella fusca (Hinds), which if present in high enough numbers can retard development of cotton seedlings.

Infestation counts were begun as soon as sufficient squares became available. Each sample consisted of 50 squares one-third grown or larger at random points in each area. Insecticide applications were begun only in those areas where boll weevil infestation levels approached 25 percent square damage. Once initiated in an area insecticide applications were continued on a 4 to 5 day interval throughout the cotton growing season. In tests where the control field required treatment prior to the field bordered by the early planted "trap" strips, fruiting samples were taken at random points within both fields. These samples were taken in the two fields on the respective dates each received the initial insecticide application. Each fruiting sample consisted of all forms on 10 linear feet of row which were considered mature enough for boll weevils to attack. The number of squares and bolls per acre could be calculated from these samples, thus providing a basis for comparing the relative maturity between the two fields when treatment was required. Infestation counts were discontinued at the initiation of overall insecticide treatment.

Test 1 was located on the Ben Huff farm near Waterproof, Louisiana. This test was composed of 2 rectangular 10-acre fields planted April 21, 1965. Along each side of one of the fields an

8-row strip of cotton was planted April 12, 9 days prior to the general planting date. The total area of the field planted in the 2 border strips was approximately 1 acre. The second field served as the control.

Test 2 was located on the W. P. Keyes farm near Waterproof, Louisiana. It was composed of 2 rectangular 10-acre fields planted April 28, 1965. Along each side of one field a 16-row strip of cotton was planted April 9, 19 days prior to the general planting date. Approximately 2 acres were planted in the border strips. As in test 1, the second field served as the control.

Test 3 was located on the Louis Johnson farm near St. Joseph, Louisiana. It was composed of 2 rectangular 6-acre fields. One field was planted May 10, 1965, with the exception of an 8-row strip on each side which was planted April 21. The two 8-row strips comprised approximately one acre. The planting date of the second field, designated as the control field, was delayed until May 18 because of mechanical failure of planting equipment.

During 1966 three additional tests were conducted. Two were located on land farmed by Louis Johnson of St. Joseph, Louisiana. The first (test 4) involved two rectangular fields, each consisting of 3.5 acres. Both of these fields were planted May 19. Along each side of one of the fields a 6-row strip of cotton was planted May 11, 8 days prior to the general planting date. The two 6-row border strips comprised approximately one-half acre. The second (test 5) was composed of two 8-acre fields planted May 26. One of these fields was bordered by 6-row strips of cotton planted May 12, 14 days prior to the general planting date. The 6-row border strips comprised approximately one acre. In both tests the field not bordered by early planted strips served as a control.

Test 6 was located on the Northeast Louisiana Branch Experiment Station at Winnsboro, Louisiana. It consisted of two 2-acre fields planted May 5. One field was bordered by a 6-row strip of cotton on each side which was planted April 20. The early planted border strips comprised approximately one-fourth acre. The second field was utilized as a control.

Results and Discussion

In Test 1 boll weevil movement from overwintering areas seemed to be to the more mature, early planted border strips as is indicated by data in Table III. Boll weevil buildup in the border strips began in early June and by late June square damage had exceeded 20 percent. Treatment was begun on the early planted strips July 7 when the infestation averaged approximately 20 percent, but individual counts ran as high as 30 percent and emergence of the first generation was imminent.

Overall treatment began July 28; however, at this time treatment was actually needed on the check only. Unfortunately, on this date both fields were inadvertently sprayed by the cooperating grower. The check, under no influence from the early planted strips, averaged over 30 percent boll weevil damaged squares while the area with early planted border strips averaged less than 15 percent. By comparison of data from the check and the field with the border

Table III. Infestation record of the boll weevil, *Anthonomus grandis* Boheman, in test 1, Huff farm, 1965

Date	Average number damaged squares per 50-square sample		
	Border rows	Middle	Control
6-8	2.3	-	-
6-15	7.0	-	-
6-22	10.3	0.0	2.0
6-29	5.5	0.0	0.6
7-6	9.5	0.2	1.9
7-14	4.0	0.4	1.6
7-22	2.8	3.7	9.5
7-28	14.8	7.3	15.8

strips it can be seen that boll weevil buildup was considerably slower in the latter. This area possibly would not have required treatment for another week or so. This retardation in boll weevil buildup probably resulted from many of the overwintered weevils from the area having been killed by early insecticide treatments in the border strips. Fruiting counts were not made in this test because no difference was expected since treatment was begun on the check and the area bordered by the "trap" rows on the same date.

In test 2 initial counts in all area showed considerable boll weevil damage, indicating that overwintered boll weevils settled throughout the test (Table IV). A large number of the overwintered weevils, however, settled in the border strips as the early infestation in that area indicates. Insecticide applications were begun on the border strips June 18 in order to reduce the number of weevils. The fact that numerous boll weevils settled in the early planted rows is also evident in that the infestation in that field was consistently only one-half that of the control field. As further evidence, the control field required insecticide applications beginning July 6, whereas, treatment in the field bordered by the early planted rows was delayed for 10 days or until July 16. Data presented in Table V show that at this stage of development 10 days resulted in a considerable difference in number of fruiting forms present per acre. The area bordered by the early planted "trap" rows contained approximately one-third more fruiting forms when it required treatment than did the control when it reached a comparable infestation level. More of the overwintered boll weevils

Table IV. Infestation record of the boll weevil, *Anthonomus grandis* Boheman, in test 2, Keyes farm, 1965

	Average number damaged squares per 50-square sample		
Date	Border rows	Middle	Control
6-8	12.8	-	-
6-15	22.8	-	-
6-22	10.3	4.3	7.5
6-29	4.0	3.5	8.0
7-6	11.3	6.7	17.3
7-16	16.8	17.5	22.8

Table V. Fruiting data taken at time of required treatment of respective fields in test 2, Keyes farm, 1965

Area	Date planted	Date of sample	Sample number	Squares per 10 row feet	Calculated no. squares per acre	Bolls per 10 row feet	Calculated no. bolls per acre
Check	4/28/65	7/6/65	1	135	176,418	60	78,408
			2	185	241,758	75	98,010
			3	141	184,258	55	71,874
			4	209	273,121	87	113,691
			5	118	154,202	43	56,192
			6	183	239,144	78	101,930
				$\bar{x}$=162	$\bar{x}$=211,483	$\bar{x}$=66	$\bar{x}$= 86,864
Area bordered by early planted rows	4/28/65	7/16/65	1	133	173,804	71	92,783
			2	257	335,848	123	160,736
			3	170	222,156	86	112,384
			4	332	433,857	135	176,418
			5	210	274,438	109	142,441
			6	305	398,574	117	152,896
				$\bar{x}$=235	$\bar{x}$=306,445	$\bar{x}$=107	$\bar{x}$=139,609

might have settled in the early planting had not the seedling emergence been very low resulting in an extremely sparse stand.

Data from test 3 are presented in Tables VI and VII. It was apparent from the initial samples that hibernated boll weevils concentrated in the early planted strips. The strips were planted April 21, 19 days prior to the remainder of the field, giving them a considerable size and height advantage. Insecticide treatment was started on the border strips June 30 at which time the area bordered by them was just beginning to fruit. The insecticide treatments on a regular schedule of 4-5 days reduced the boll weevil infestation and held it at reasonably low levels in the border rows until the middle of August when the cotton in the strips was maturing. No subsequent applications of insecticide were necessary on these strips after August 17.

In the area bordered by the "trap" strips no boll weevil damaged squares were found until after first generation emergence in the "trap" rows. The number, however, remained extremely low throughout July and August. Infestation never reached 20 percent in the area bordered by the "trap" rows. The control field on the other hand, even though it was planted 8 days after the test area, showed evidence that numerous hibernated boll weevils had settled there. Infestation increased until it exceeded 35 percent by August 10 and insecticide was applied.

Insecticide applications were begun on the area bordered by the "trap" rows August 25. This treatment was not directed at the boll weevil, however, but to a late season infestation of

Table VI. Infestation record of the boll weevil, *Anthonomus grandis* Boheman, in test 3, Johnson farm, 1965

	Average number damaged squares per 50-square sample		
Date	Border rows	Middle	Control
6-8	17.0	-	-
6-15	23.8	-	-
6-22	32.5	-	-
6-30	24.2	0.0	-
7-7	12.2	0.0	1.3
7-14	1.8	0.0	3.8
7-22	2.5	1.2	0.8
7-28	1.8	0.2	5.8
8-4	12.2	1.5	6.3
8-10	20.3	8.2	18.2
8-17	1.7	8.8	26.8
8-25	-	6.8	40.0

<u>Heliothis</u> spp. During the month of August it had been observed that predaceous insects were present only in very low numbers. Factors causing the decline are not known, but it was strongly suspected that the decline in numbers of beneficial species allowed the build-up of <u>Heliothis</u> spp. Similar increases in <u>Heliothis</u> spp. numbers have been associated with an insecticide application which eliminated beneficial arthropods.

Insecticide applications were begun on the control field 84 days after planting, but not on the area bordered by the early planted strips until 107 days following planting. This represented a 23-day difference and the difference probably would have been greater had not the <u>Heliothis</u> infestation developed. The difference in maturity resulting from these 23 days can be seen in Table VII. The area bordered by the "trap" rows had significantly more bolls than the control and was rapidly approaching maturity when insecticide applications were begun. This area had a cotton crop practically matured when insecticide treatment was initiated as compared to the control which was only approaching its peak fruiting period.

The plants in the "trap" strips appeared to be much more attractive to overwintered boll weevils in this test probably because of a greater difference in plant size and development as a result of the 19-day difference in planting dates. Also fruiting did not begin in the area bordered by the "trap" rows until late June which probably was a factor in the overall success of the test. It is reasonable to assume that the majority of the overwintered boll

Table VII. Fruiting data taken at time of required treatment of respective fields in test 3, Johnson farm, 1965

Area	Date planted	Date of sample	Sample number	Squares per 10 row feet	Calculated no. squares per acre	Bolls per 10 row feet	Calculated no. bolls per acre
Check	5/18/65	8/10/65	1	264	344,995	116	151,588
			2	258	337,154	132	172,498
			3	200	261,360	80	104,544
			4	137	179,031	64	83,635
			5	179	233,917	85	111,078
			6	153	199,940	75	98,010
				$\bar{x}$=199	$\bar{x}$=259,400	$\bar{x}$=92	$\bar{x}$=120,226
Area bordered by early planted rows	5/10/65	8/25/65	1	134	175,111	263	343,688
			2	106	138,521	284	371,131
			3	128	167,270	258	337,154
			4	152	198,633	223	291,416
			5	98	128,066	193	252,212
			6	113	147,668	289	377,665
				$\bar{x}$=122	$\bar{x}$=159,211	$\bar{x}$=252	$\bar{x}$=328,878

weevils in the vicinity had already migrated to the fields by this time and evidently concentrated in the more mature border strips where squares suitable for food and oviposition were available.

Data obtained through weekly samples in test 4 are presented in Table VIII. This test was in the same location as test 3 conducted the previous year. Data from this test show that boll weevil infestation in the test area was unusually low. Square damage did not exceed 10 percent until the second week in August and at that time the infestation was very uniform. The uniformity of infestation was thought to be a result of hibernated boll weevils exhibiting no preference for the border strips in this test and simply settling randomly throughout the area upon entering the field. Apparently the one-week difference in planting dates in this test was not enough to give the border rows the size advantage necessary for increased attractiveness to overwintered boll weevils. Further evidence of the random distribution of the overwintered weevils in this test is shown in data from the final sampling. The sharp rise in infestation which occurred just prior to the final sampling date was due to emergence of second generation boll weevils. This infestation increase was evident throughout the test area and necessitated overall treatment beginning August 17. Therefore, no cotton fruiting data was taken since no difference in fruiting or maturity could be expected.

Data from test 5 are presented in Tables IX and X. In test 5 there was a 2-week difference in the planting dates of border rows and the remainder of the test, thereby giving the border strips a

Table VIII. Infestation record of the boll weevil, *Anthonomus grandis* Boheman, in test 4, Johnson farm, 1966

	Average number damaged squares per 50-square sample		
Date	Border rows	Middle	Control
6-28	2.5	-	-
7-7	1.8	0.7	3.2
7-15	0.7	0.0	0.2
7-22	0.7	0.0	0.3
7-27	3.3	0.8	0.3
8-4	3.5	3.7	1.5
8-9	5.2	6.3	4.7
8-17	26.0	22.5	17.0

noticeable size advantage. Apparently the age difference had a marked effect because the infestation records of the three areas shown in Table IX indicate that overwintered boll weevils congregated in the border strips. The congregation was evident because of the high level of boll weevil damaged squares which occurred in the border rows necessitating insecticide application beginning July 15. Boll weevil numbers in the early planted border rows were subsequently reduced as the decline in square damage indicates. The area situated between the border rows, however, had only negligible boll weevil damage until early in September, further indicating that overwintered boll weevils in the area had congregated in the "trap" strips. Data from the control field provides additional evidence since boll weevil infestation in this field was relatively high initially and increased rapidly until it exceeded 25 percent in late July. Insecticide applications were begun on the control in addition to the border strips July 27. Boll weevil infestation remained at a low level in the area bordered by the early planted strips until September. At this time the percent infestation increased rapidly. This was considered largely the result of the decline in squaring due to maturity. Also, adjacent fields had matured resulting in considerable boll weevil movement into fields where squares were still available. Insecticide application was begun in the area bordered by the "trap" rows September 7 chiefly to protect small bolls since there were very few squares remaining as can be seen in Table X.

Table IX. Infestation record of the boll weevil, *Anthonomus grandis* Boheman, in test 5, Johnson farm, 1966

	Average number damaged squares per 50-square sample		
Date	Border rows	Middle	Control
6-28	5.7	-	-
7-7	6.6	0.0	1.5
7-15	11.6	0.0	3.5
7-22	7.5	0.9	6.7
7-27	0.9	0.4	13.8
8-3	0.7	0.7	9.8
8-9	1.4	0.9	5.6
8-17	1.8	1.0	14.3
8-22	3.0	4.2	38.7
8-29	-	7.9	41.8
9-7	-	20.2	-

Table X. Fruiting data taken at time of required treatment of respective fields in test 5, Johnson farm, 1966

Area	Date planted	Date of sample	Sample number	Squares per 10 row feet	Calculated no. squares per acre	Bolls per 10 row feet	Calculated no. bolls per acre
Check	5/26/66	7/27/66	1	129	168,577	56	73,181
			2	127	165,964	13	16,988
			3	81	105,851	32	41,818
			4	75	98,010	18	23,522
			5	71	92,783	48	62,726
			6	167	218,236	31	36,590
				$\bar{x}$=108	$\bar{x}$=141,566	$\bar{x}$=33	$\bar{x}$=42,471
Area bordered by early planted rows	5/26/66	9/7/66	1	26	33,977	198	258,747
			2	33	43,124	175	228,690
			3	10	13,068	171	223,463
			4	27	35,284	228	297,950
			5	20	26,136	214	279,655
			6	69	90,169	144	188,179
			7	8	10,454	213	278,348
			8	0	0	165	215,622
			9	6	7,841	186	243,065
				$\bar{x}$=22	$\bar{x}$=28,893	$\bar{x}$=188	$\bar{x}$=245,965

There was an interval of 42 days between the date the control field required insecticide application and the date the field bordered by early planted rows required insecticide treatment. These 42 days represented the major period of cotton fruiting (Table X). There were significantly fewer bolls in the control field when it required treatment as there were in the field bordered by the "trap" strips when it reached a similar level of infestation. Plants in the control field, however, did possess significantly more squares. This also indicated considerable difference in maturity of the two areas at time of required treatment.

Table XI presents results obtained in test 6 which was located at Winnsboro, Louisiana. These data show that boll weevil infestation in this location was extremely low throughout the cotton fruiting season. None of the plantings in this test developed a boll weevil infestation level which justified application of insecticide. Only one sample date showed an infestation of over 10 percent and that occurred in the control field late in the season when very few squares were present. The Macon Ridge on which Winnsboro is located is characterized by relatively moderate boll weevil infestations during most years. Unusually hot, dry weather during June and July caused high mortality of immature boll weevils resulting in the moderate initial population being further reduced. Therefore, data from this test were of little value in determining whether "trap plantings" might be used as a tool in boll weevil control programs.

Table XI. Infestation record of the boll weevil, *Anthonomus grandis* Boheman,in test 6, Winnsboro, 1966

	Average number damaged squares per 50-square sample		
Date	Border rows	Middle	Control
6-15	0.0	-	-
6-22	0.7	-	-
6-28	1.6	0.0	1.0
7-7	1.5	0.0	0.3
7-15	0.2	0.0	0.2
7-22	1.5	0.3	0.3
7-27	0.0	0.0	0.0
8-3	0.7	0.3	0.9
8-9	0.0	0.8	1.2
8-17	-	0.5	2.8
8-23	-	4.3	6.5

Data from these tests show that overwintered boll weevils can be expected to congregate in early planted border rows of cotton provided The difference in planting dates is sufficient to give a distinct difference in size of plants. Insecticides applied on areas of boll weevil concentration can be expected to retard buildup of boll weevil populations in adjacent areas, therefore, delaying the date at which overall insecticide treatment must be initiated.

SECTION II

PLANT RESISTANCE STUDIES

It has been reported that the boll weevil, *Anthonomus grandis* Boheman, exhibits a nonpreference toward cotton varieties which possess genetic characters for red foliage. Studies were undertaken to verify reports of nonpreference and to determine whether this lack of preference could be utilized in boll weevil control programs.

Literature Review

With the development of resistance to the chlorinated hydrocarbon insecticides by the boll weevil (Roussel and Clower, 1955) entomologists began to realize that additional means must be employed in control of this insect. The numerous (and at times excessive) insecticide applications directed at the boll weevil have tended to favor the development of other insect problems by destroying predatory and parasitic forms. In addition the ever increasing problem of insecticide drift, environmental contamination, and residues demands utmost consideration (Akesson and Yates, 1964). This calls for an adjustment of the insecticidal program, with a reexamination of indirect control methods including the development of resistant cotton varieties (Anonymous, 1957). A well rounded insect control project should include the use of varieties known to be resistant and a search for new sources of resistance.

Painter (1958) reported that plants which are inherently less damaged or less infested than others under comparable environmental conditions in the field have been termed resistant. He also places these plants into three categories according to the nature of their resistance. In the first group are those plants which are non-preferred for oviposition, shelter or food, primarily because of lack of certain qualities. In the second group are placed plants which may affect the biology of the insect adversely. The third group includes plants that are capable of surviving levels of infestation that would kill or severely injure susceptible plants.

Possible resistance of the cotton plant to insects, particularly the boll weevil, has been of interest to researchers for many years. During the early years of the boll weevil invasion of the United States the principle of host evasion was utilized in attempts to control the pest. Early researchers such as Flynn (1907) advanced the hypothesis that if all cotton were planted late in the season most hibernated boll weevils would die of starvation. Therefore, the damage to the later planted crop by this pest would be reduced or negligible. To test this hypothesis experiments were undertaken during 1906 in the late planting of cotton in western Louisiana. Results from these experiments showed that late planting of cotton resulted in increased boll weevil infestations and decreased yields. Newell and Rosenfield (1909) also pointed out disadvantages of late planting of cotton to avoid boll weevil injury.

Shortly thereafter, use was made of the principle of host evasion by replacing the late maturing cotton varieties with more determinant, early maturing ones. Emphasis was placed on getting the fruit set as soon as possible to avoid the ravages of midsummer boll weevil populations (Bennett, 1908; Cook, 1912; Hunter, 1909, 1912, 1917, 1922; Hunter and Coad, 1923; Ware, 1925; Isely, 1934). They reported that production of an early crop was important enough to warrant selection for early varieties by researchers. Varieties were recommended which matured very quickly, setting a crop no later than late July. Hunter and Coad (1923) revealed that the invasion of the boll weevil had brought about the replacement of the long staple and large boll varieties of cotton by small boll, early varieties of very short staple cotton.

During the early years of the boll weevil invasion of the United States several expeditions were sent to Mexico and Central America to seek weevil-resistant cottons. It was considered that for the cotton plant to have survived the ravages of the boll weevil throughout the history of their coexistence some degree of natural resistance must be exhibited by the plant somewhere within its range. Emphasis was placed largely on host evasion and on characteristics of the cotton plant that were thought to be distasteful or detrimental to the weevil (Cook, 1904, 1906; Ware, 1936). Some of the characteristics that were considered of possible value were small or deeply lobed leaves, hairy stems and leaves, earliness, and extra floral nectaries to attract predaceous insects.

Cook (1904) reported that a dwarf upland type of cotton native to eastern Guatemala was much less injured by the boll weevil than was a nearby tree of perennial cotton. Further investigations revealed that the kelep or Gautemalan cotton boll weevil ant, a predator of the boll weevil, was attracted to this type of cotton by the copious production of nectar from two sets of extra floral nectaries on the involucral bracts. A few weevils were found on this cotton, but they were apparently held at a very low level by the predaceous habits of the kelep ant.

Ware (1936) reported that attempts to cultivate the dwarf Guatemalan cotton variety in various cotton-growing regions of the United States was unsuccessful. He also reported that another Guatemalan cotton variety, which produced extremely small involucral bracts that enabled turkeys to find the weevils and devour them, was experimentally tested in the United States but without success.

The ability of plants to proliferate cells resulting in mechanical destruction of boll weevil eggs and young larvae was studied in detail by Hinds (1906) and Smith (1936). Hinds said, "Proliferation is simply a manifestation of a natural inherent tendency of plant cells to respond to an encountered irritation by multiplying or forming new cells. It is evidently a method of self-defense, and in the case of cotton the irritation appears to be in nearly all cases strictly mechanical. The function of proliferation in most cases is undoubtedly to repair an injury." He reported that in a large number of varieties of American upland cotton proliferation has been found to occur in 51 percent of the cases of weevil attack upon squares and in 55 percent of the cases of similar attack upon bolls. Proliferation was found to increase mortality of immature stages by 13.5 percent in squares and 6.3 percent in bolls. He suggested the need for selection of new strains of cotton which exhibit a greater tendency toward proliferation, however, he felt that complete reliance could never be placed in natural factors for a solution of the boll weevil problem.

Smith (1936) included climate, parasites, predators, and proliferation as causes of mortality of boll weevil stages within the squares. Climate was by far the most effective of the factors followed in order of efficiency by parasites, predators, and proliferation. Summary of square examinations made in this study extending over the years 1929-32 showed that death of immature stages of the boll weevil due to proliferation reached a maximum of 1.71 percent. Usually mortality due to proliferation was considerably less than 1.0 percent.

Thorough investigations into the success of the boll weevil on sea island varieties, Gossypium bardadense, as compared to the upland cotton varieties, G. hirsutum, have been conducted (Smith, 1921; Cook and Doyle, 1927). According to Smith there was little difference in the longevity or fecundity of weevils fed on the two species of cotton, however, 49.4 percent of the immature stages emerged as adults from the sea island squares compared to 36.9 percent in upland squares. In contrast, 1,500 upland bolls produced 100 weevils while the same number of sea island bolls produced 650 weevils. Cook and Doyle believed that this latter was due to the thinner walls of the bolls of sea island cottons.

Such characteristics as hairiness of stem and leaves were considered as possible sources of resistance by early workers (Hunter and Pierce, 1912). Stephens (1957) in a study of sources of resistance of cotton strains to the boll weevil lists plant hairiness as a possibility. Wannamaker (1957) in a study of the effect of plant hairiness on boll weevil attack reports that excessively hairy varieties such as Pilose received significantly less boll weevil damage than the other types included in the experiment. Wessling (1958a and 1958b) in studies very similar to those of Wannamaker agreed that the Pilose strain showed a significantly lower proportion of egg-laying punctures. Merkly and Meyer (1963) reported that the Pilose strain demonstrated only an intermediate degree of resistance when compared to a series of varieties.

The preference aspects of resistance to the boll weevil in cotton varieties have received some attention during the past fifty years. Painter (1951) stated that the scarcity of boll weevils on other plants in the neighborhood of cotton indicates the highly obligate relationship of the insect to the host plant and the possibility of resistance through a lack in some feature of the attractiveness. He was of the opinion that leaf color is one such factor.

Results of a series of observations on the boll weevil's sense of color obtained by R. Jones in 1907 were reported by Hunter and Pierce (1912). In this series of observations, boll weevils were given the opportunity to enter tubes of different colors from a box. Among the colors tested were green and red. Green was found to be more attractive than red by a ratio of 6.0 to 3.8.

Tests conducted by Isely (1927 and 1928) in Arkansas indicated that the boll weevil exhibits a marked preference for cotton plants with green foliage to those with red foliage. Without exception plots of the Winesap (redleaf) variety were less heavily infested than the adjacent plots containing green plants. Isely was of the opinion that no economic importance could be attached to the apparent degree of immunity of red leafed cotton, since at that time there was no red leafed variety which agronomists recommended for commercial planting. Isely also suspected that the apparent immunity might disappear if only red cotton was available.

Stephens (1957) in his review of possible sources of resistance to the boll weevil in cotton lists red leaf color. Wessling (1958a) reported that the redleaf strain included in tests of plant resistance exhibited a rather high degree of resistance. He was of the opinion that the main cause of the resistance was nonpreference for the redleaf strain by the boll weevil. According to Hunter and Waddle (1958) over 300 biotypes of cotton were screened in Arkansas during 1957 and 1958 for resistance to the boll weevil. Red foliage strains were cited as examples of nonpreference. In laboratory tests conducted by Stephens and Lee (1961) boll weevils indicated no preference in feeding or oviposition for red or green cotton buds. Merkl and Meyer (1963) in an extensive study of resistance of cotton strains to the boll weevil reported that red plants were less attractive than were green plants. These authors stated, however, that since boll weevils fed and reproduced readily on the red plants when no green plants were available, color would not be an important factor in commercial plantings. Given a choice, boll weevils preferred green cotton, but if green cotton were not available weevils would thrive on red cotton. Jones et al. (1964) reported that tests conducted from 1960 to 1963 evaluating the comparative preference by the boll weevil for certain biotypes of cotton resulted in definite nonpreference for a red foliage biotype when compared to a standard green foliage biotype. In laboratory experiments conducted by Mitlin et al. (1966) the influence of color on the feeding of boll weevils was determined by the response of weevils to feeding plugs dyed red, orange, yellow, green, blue, or violet, and to undyed plugs. The boll weevils preferred the dyed to the undyed plugs, but discriminated little among the dyed plugs. These authors suggest that plant breeders should not consider color as a major character in developing cotton strains resistant to boll weevils.

A STUDY OF PREFERENCE OF THE BOLL WEEVIL FOR COTTON SELECTIONS WITH GREEN OR RED FOLIAGE

The objective of this study was to determine if the boll weevil would exhibit a measurable nonpreference toward a cotton variety with red foliage.

Procedure

This test was located on the Northeast Louisiana Experiment Station at St. Joseph. It consisted of two treatments, Stoneville 7 (red foliage character) and Stoneville 7A (green foliage character), randomized and replicated four times. Individual plots were composed of 16 rows, 65 feet 4 inches in length and comprising approximately one-twelfth of an acre. The test area was located in Commerce sandy loam soil fertilized with 88 pounds of N as NH^3 prior to planting. With the onset of squaring, 100 squares were examined in each plot for boll weevil damage. Insecticide applications were begun on a treatment when boll weevil damage to squares approached 25 percent. Sampling was discontinued when boll weevil infestation reached a level at which both treatments warranted insecticide application.

Results and Discussion

Results obtained from this test are presented in Table XII. Data in this table show the results of weekly square samples for boll weevil damage. These data show that boll weevil infestation was consistently higher in the green foliage selection than in the red foliage selection. Throughout the 6-week sampling period boll weevil damaged squares were 2 to 4 times higher in the green selection than in the red. The final samples were taken in this test July 21. Samples collected on this date indicated tremendous increase in boll weevil damage. This increase in damage was considered to have been caused by the emergence of 1st generation boll

Table XII. Boll weevil infestation in Stoneville 7 (red foliage) selection and Stoneville 7A (green foliage) selection, N. E. Station, St. Joseph, Louisiana, 1965

	Average number damaged squares per 100-square sample	
Date	Red selection	Green selection
6-17	1.2	3.0
6-23	1.5	5.0
7-1	1.0	2.0
7-7	2.3	3.8
7-16	5.8	21.5
7-21	20.3	44.5

weevils the previous week. Insecticide applications were begun on both entries following the sampling on this date. The infestation in the red selection, while only half that of the green, nevertheless, warranted insecticide application at the same time.

These data indicate that a considerably larger number of overwintered boll weevils either settled or moved into the green foliage selection in preference to the red. Apparently there is a nonpreference factor involved, however, it is probably discernible only when a choice between the two is available. The rapid increase in infestation in both strains following first generation boll weevil emergence in mid-July provided sufficient evidence that the red strain is an entirely suitable host.

Yield data were taken to determine whether production differences could be expected between the two selections. These data revealed that yield of seed cotton in the red foliage strain was only two-thirds that of the green strain. It is possible that the genetic character responsible for red foliage is associated with low yield. Yield data from this test agrees with previous work reported by Isely (1928) where low yields were associated with strains having red foliage.

USE OF A RED FOLIAGE SELECTION IN TRAP CROP STUDIES

The objective of these studies was to determine the degree of nonpreference that would be exhibited by the boll weevil to cotton selections possessing red foliage and to determine if this would be of value in control programs.

Procedure

Trap-crop tests were designed to utilize the nonpreference exhibited by boll weevils to cotton strains possessing red foliage. Each test consisted of a single cotton field planted to the red foliage strain and bordered on each side by a narrow strip planted to a normal green foliage strain. In all tests the border strips of the green selection and the red selection were planted on the same date. The purpose of this design was to have the green foliage selection situated between the red foliage selection and boll weevil overwintering sites. It was thought that overwintered boll weevils in the area would concentrate in the narrow border strips of green cotton because of the availability of the green cotton and their nonpreference for the red foliage. Success of the test design would be considered evident if infestation within the green border rows reached a predetermined level at which insecticide application was necessary prior to the time the red foliage plants became equally infested.

Test 1 was located on Osceola Plantation five miles north of St. Joseph, Louisiana. The test area consisted of a 10-acre field of which approximately a one-acre strip on either side was planted to the Stoneville 7A (green foliage) selection and the remainder of the field to Stoneville 7 (red foliage). Both selections were planted during the first week in May, 1965.

Tests 2 and 3 were of the same design as test 1, but each was approximately half the size. These two tests were located on the Northeast Branch Experiment Station at Winnsboro, Louisiana. Test 2 was conducted during the 1965 cotton-growing season, whereas, test 3 was conducted during 1966.

With the onset of fruiting, 50 squares were examined at four locations within both strains for boll weevil damage. Insecticide applications were started only in those areas where boll weevil damage to squares approached or exceeded 25 percent. Sampling was discontinued in all tests with the beginning of overall insecticide treatment.

Results and Discussion

Results from test 1 are presented in Table XIII. These data show that the number of boll weevil damaged squares in the green border strips was consistently higher than in the red foliage planting. During July square damage in the border strips was approximately twice that in the red. Even though square damage was considerably greater in the green border strips insecticide applications were required on the whole test July 21. Samples taken on this date revealed that both selections had reached or exceeded 25 percent square damage following 1st generation boll weevil emergence the previous week. Therefore, in this test boll weevils did show some preference for the green border strips, but not enough so that it could be utilized successfully in any type of control program.

Results obtained from test 2 are presented in Table XIV. These data show decisive differences in response to the two strains by the boll weevil. Throughout the sampling period the infestation was much greater in the green border strips. The concentration of

Table XIII. Boll weevil infestation in Stoneville 7 (red foliage) selection and Stoneville 7A (green foliage) selection, Osceola Plantation, 1965

	Average number damaged squares per 50-square sample	
Date	Red selection	Green selection
6-15	1.3	1.3
6-22	1.8	2.8
6-29	0.0	3.4
7-6	2.0	1.5
7-13	2.5	7.3
7-21	12.0	26.5

Table XIV. Boll weevil infestation in Stoneville 7 (red foliage) selection and Stoneville 7A (green foliage) selection, Winnsboro, Louisiana, 1965

	Average number damaged squares per 50-square sample	
Date	Red selection	Green selection
6-16	0.8	4.3
6-23	2.0	4.0
6-30	1.8	4.3
7-7	0.0	14.5
7-14	1.0	9.3
7-21	5.0	16.0
7-27	6.8	17.0
8-4	19.0	13.0

weevils in the border strips was thought to be due to nonpreference for the red strain as well as availability or nearness to overwintering sites of the border strips. The boll weevil infestation exceeded 30 percent in the border strips July 21 and insecticide applications were begun to prevent boll weevil movement into the remainder of the field. Sampling was discontinued August 4 due to maturity of the cotton. A severe drought during July hastened maturity in cotton throughout the test area. The infestation on the final date indicated need for insecticide treatment in the red strain. However, the increase in percentage of boll weevil damaged squares was primarily a result of the scarcity of squares caused by early maturity of the cotton. Insecticide application was not considered necessary on the red foliage strain since this selection was mature. Insecticide treatment was discontinued in the green foliage border strips August 8 after a total of five applications. In this test boll weevils concentrated in the border strips of a green cotton selection in preference to the red selection. Once population numbers increased in these strips, insecticide was applied to reduce numbers and movement of boll weevils into the red strain. It is considered that the design of the test, nonpreference for the red foliage selection by the boll weevil, and early maturity of cotton due to drought were the factors responsible for the results obtained in this test.

Results from test 3, located at Winnsboro, Louisiana during 1966, are presented in Table XV. Data in this table show that the boll weevil infestation developed very slowly. Extremely dry

Table XV. Boll weevil infestation in Stoneville 7 (red foliage) selection and Stoneville 7A (green foliage) selection, Winnsboro, Louisiana, 1966

	Average number damaged squares per 100-square sample	
Date	Red selection	Green selection
6-28	0.0	1.0
7-7	0.0	0.5
7-15	0.0	0.0
7-22	0.3	1.3
7-27	0.0	0.0
8-3	0.8	1.8
8-9	1.3	1.5
8-17	2.3	4.3
8-23	3.5	12.5
8-29	9.8	26.5
9-7	26.5	25.8

conditions during June and July were though to have been responsible for this. Rain which occurred during early August and boll weevil movement from mature fields of cotton were responsible for an increase in boll weevil damage in the test. The increase was more pronounced in the green border rows, necessitating insecticide application August 29, one week prior to a need for application in the red foliage strain. In this test there was very little difference in development of boll weevil infestations between both strains. The lack of differences can probably be explained by the movement of boll weevils from nearby matured cotton fields into the test area and also the maturation of the plants in the test field. Boll weevils which moved from nearby fields in search of food seemed to settle wherever cotton squares were available irrespective of foliage color. The test field matured to such an extent that insecticide applications were discontinued September 15.

SECTION III

BOLL WEEVIL SEX ATTRACTANT STUDIES

Results of laboratory and field studies have shown that the male boll weevil emits a substance (sex attractant or excitant) which initiates a definite response by females of the species. The present study was conducted in order to acquire further information on field behavior of the boll weevil in response to the sex pheromone. A secondary purpose of this study was to determine if the male thurberia weevil, A. grandis thurberiae Pierce, is attractive to boll weevil populations in the field.

Literature Review

"Insects have managed to persist in hostile surroundings because they have developed extraordinary adaptations or abilities, one of which is a highly specialized sense of smell. Some insects can follow unerringly an odor trail to a source of food, to host plants and animals, to the opposite sex, or to the right place to lay eggs. Because many insects depend for their survival on these odors, frequently they can be attracted by means of a chemical to a trap for detection purposes, or to a toxicant that destroys the insect, or to a substance which makes them incapable of fertile mating" (Jacobson and Beroza, 1963).

According to Jacobson (1965) attractants may be classified as sex, food, or oviposition lures. The type of lure is inferred by the behavior of the insect. A chemical is probably a sex attractant if it brings to it an insect, which then assumes a mating position. These sex attractants, usually released by the female insect, are important links in the process by which the opposite sexes locate each other for mating. Although odors released by female insects are usually for the purpose of attracting males from a distance, they may also serve merely to excite the male sexually before copulation. Sexual odors released by males are primarily for the purpose of sexually exciting the female, making her more receptive to the male's advances, rather than long-range attractants.

A complete review of insect sex attractants is beyond the scope of this study. Extensive reviews of the subject were made by Karlson and Butenandt (1959) and Jacobson (1965).

Several studies concerned with sex attractants have been conducted with various species of cotton insects. Most of this research has concerned lepidopterous species, largely because of the frequency with which sex attractants have been exhibited in this order and also because of the economic importance of the order. Gentry *et al*. (1964) demonstrated the presence of a female sex attractant in the tobacco budworm, *Heliothis virescens* (F.). Berger *et al*. (1965) confirmed the presence of the female sex attractant in the tobacco budworm and also reported the presence of such an attractant in the bollworm, *Heliothis zea* (Boddie). Flaschentrager *et al*. (1957) reported that a chemical sex attractant for male pink bollworm moths is produced by the females. Ouye and Butt (1962) reported the successful extraction of the pink bollworm sex attractant. Later, Jones et al. (1966) reported on the isolation, identification and synthesis of the pink bollworm sex attractant. Ignoffo et al. (1963) reported the presence of a sex attractant in the female cabbage looper, Trichoplusia ni (Hubner). Shorey et al. (1964) substantiated these findings with a report on a quantitative bioassay technique for the sex pheromone of the cabbage looper. Berger (1966) later reported the isolation, identification, and synthesis of the cabbage looper sex attractant. A paper by Gaston and Shorey (1964) revealed that the sex pheromones of cotton pests Prodenia ornithogalli Guenee, Spodoptera exigua (Hubner), H. zea (Boddie), and H. virescens (F.) have also been successfully bioassayed by the same technique.

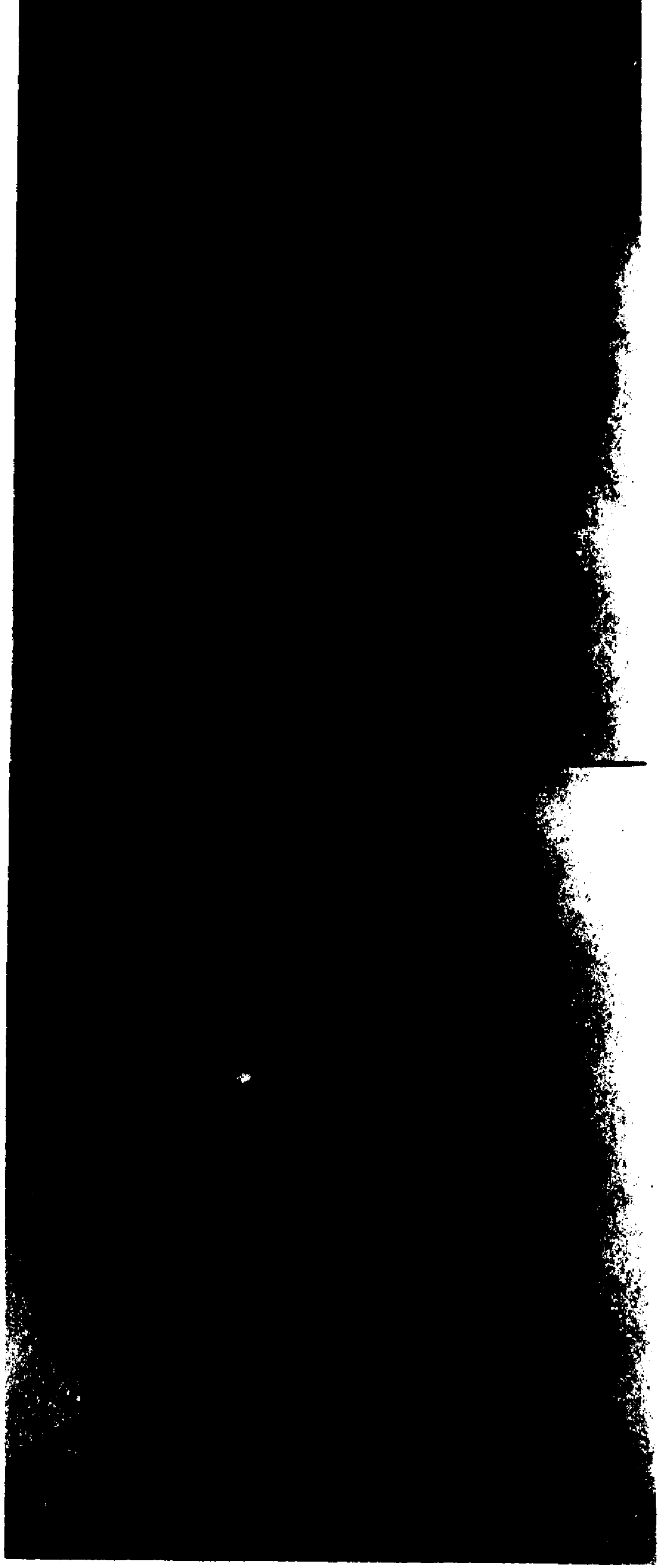
Keller et al. (1964) reported that a substance produced by male boll weevils attracted females for mating purposes. Air drawn continuously over males in a cage was passed through charcoal, which was then extracted with chloroform. Removal of the solvent from the extract yielded a substance to which females quickly responded. Response was characterized by rapid walking, standing high on their front legs, and holding their antennae high and forward.

Cross and Mitchell (1966) reported observations of mating behavior of the boll weevil in the field. Males were not observed to respond to females over distances greater than 1 or 2 inches, however, females often sought males from distances of more than 30 feet, especially from downwind positions. The authors were of the opinion that this response was due to a wind-borne pheromone released by the male.

Procedure

A trapping technique was utilized to study the field behavior of the boll weevil in response to its sex pheromone. A trap was desired which had a minimum surface area, but still possessed the capability of holding any boll weevils that were attracted to the caged weevil. Minimum surface area would increase the probability that a trapped insect had actively sought the trap rather than having accidently flown into it. A smaller surface would be easier to inspect and maintain relatively free of unwanted species. The trap designed (Plate 1) was composed of a 6 by 6-inch backboard of ½-inch plywood placed on a 6 by 4-inch stage of ¼-inch plywood. This provided a stage or balcony of 1-3/4 inches projecting at a right angle to the backboard on each side. This stage trapped any weevils that were able to free themselves from the backboard and would have otherwise fallen to the ground. A holding chamber was provided for the caged weevil by drilling a 3/4-inch hole through the main board. The weevil was held captive in the chamber by a 2-inch square of 14-mesh screen stapled on each side of the hole. The screen allowed movement of air through the cage in which the weevil was held, thereby facilitating the spread of any volatile material into the environment. A wire bail was attached to the top of the traps to aid in handling. Each trap was mounted on ½ by 2-inch stakes which varied in length according to cotton-plant height. Traps were positioned at heights comparable to that of

Plate 1. Trap used for sex attractant studies.



the plants because boll weevil activity is more pronounced in the upper areas of the cotton plant.

Traps were coated with a layer of Stikem® (active ingredients 97 percent polymerized butene, isobutene, and butane; inert ingredients 3 percent; Michel and Pelton Co., Emeryville, California) with the exception of the screened area. Stikem® was applied as a thin layer to prevent "running". Traps were cleaned and Stikem® reapplied whenever necessary.

Boll weevils used in this study were obtained from a laboratory culture of Louisiana origin. The thurberia weevils were obtained from a laboratory culture of Arizona origin. The weevils were reared at a temperature of 80° F. and a relative humidity of approximately 60 percent using a synthetic medium and rearing procedures slightly modified from that described by Earle _et al._ (1959). The modified medium contained 5 grams of acetone square powder, 3 grams of soybean protein, and 1 gram of yeast in addition to the other components. Upon emergence from pupal cells adults were sexed by methods described by Little and Martin (1942) and the sexes held separately throughout the study. Mitchell (1963) reported only 87.5 percent accuracy using this method, therefore, only those weevils that exhibited unquestionable morphological characteristics were used. Weevils were held at 80° F. and fed on fresh, debracted cotton squares for a minimum of one week before they were placed in traps in the field.

These studies incorporated 5 trap treatments; thurberia weevil male and female, boll weevil male and female, and a control which contained no insect. At each location a randomized arrangement of the 5 treatments was replicated several times depending upon available space.

Trapping was done in 1965 in Tensas Parish near St. Joseph. Traps were placed in cotton fields about 2 weeks after emergence of cotton seedlings during April and May. A total of 150 traps (30 replications) were utilized. Some of these traps remained in the field only 1 to 2 weeks, while others remained for a period of 8 weeks. Traps were removed from fields at the time of disappearance of overwintered boll weevils or when they interfered with farming practices.

In 1966 trapping was done near Clinton, Louisiana during June and near St. Joseph during late July, August, and September. Sixty traps (12 replications) were placed in fruiting cotton fields near Clinton. These traps remained in the field for a period of 3 weeks. Fifty traps (10 replications) were placed in an untreated cotton field near St. Joseph July 27. These traps remained in the field for 2 months at which time the cotton had matured and was ready for defoliation.

Boll weevils that were collected on traps were taken to the laboratory for dissection and determination of sex. Weevils to which trapped boll weevils had been attracted were also returned to the laboratory for verification of predetermined sex by dissection. Traps were examined and dead weevils replaced once a week during 1965 since trapping was done during periods of relatively mild temperatures. During 1966, however, traps were examined twice a week because of the reduced longevity of caged weevils resulting from higher average temperatures.

Results and Discussion

The results of research on behavior of boll weevils in response to the sex pheromone are presented in Table XVI. It is apparent from these data that a significant response was obtained only in the test conducted in seedling cotton at St. Joseph during the spring of 1965.

Data from studies conducted at this time revealed that traps containing males of either species were significantly more attractive than traps without weevils. These traps caught 5 to 7 times as many weevils as did the controls. Traps containing females caught 2 to 3 times as many weevils as did the controls, but this difference was not significant.

Traps containing male boll weevils caught significantly more weevils than traps containing females of either species. While considerably more weevils were caught on thurberia male traps than on traps containing boll weevil or thurberia females the difference was not significant. However, a total of 64 weevils was caught on all traps containing males and only 25 on traps containing females. The total number of weevils collected on traps containing males was significantly greater than the total number of weevils collected on traps containing females. Keller *et al.* (1964) also reported males to be more attractive in laboratory experiments.

Thirty-nine of the 64 weevils collected on traps containing caged males were females, however, this difference was not

Table XVI. Numbers of boll weevils collected on adhesive traps in cotton fields at three locations during 1965-66

Treatment	Number of boll weevils trapped		
	Male	Female	Total[a]
St. Joseph - 1965			
Boll weevil male	15	21	36 a
Thurberia male	10	18	28 ab
Thurberia female	7	8	15 bc
Boll weevil female	5	5	10 bc
Control	1	4	5 c
Clinton - 1966			
Boll weevil male	-	1	1
Thurberia male	1	-	1
Thurberia female	-	1	1
Boll weevil female	-	2	2
Control	1	2	3
St. Joseph - 1966			
Boll weevil male	12	13	25
Thurberia male	10	15	25
Thurberia female	9	8	17
Boll weevil female	13	10	23
Control	11	14	25

[a] Numbers not followed by the same letter are significantly different at the 5% level of probability according to Duncan's (1955) multiple range test.

significant. These data indicate that males are more attractive than females and both sexes respond to the males.

While Keller et al. (1964) reported that only females were attracted to males in the boll weevil, other insect species have been reported in which both sexes respond. Jacobson (1965) includes a chapter concerning attractants produced by one sex to lure both sexes, which he called assembling scents. The insect species involved are all in the order Coleoptera and are treated separately in Jacobson's text because one sex produces a substance which causes both sexes to assemble for mating. According to Jacobson a volatile substance responsible for mass attraction of both male and female of Ips confusus (Le Conte) and I. ponderosae (Sw.) is obtained from the hind gut of mature males of the respective species.

Data from trapping studies conducted during 1965 in the St. Joseph area also showed that there was no significant difference in the response of field weevils to thurberia weevils or to boll weevils. A total of 43 weevils were collected from traps containing thurberia weevils, while 46 were collected from traps containing boll weevils.

Little success was realized in trapping studies conducted in older, fruiting cotton at Clinton, Louisiana during June of 1966. Very few weevils were trapped and as many were caught on the controls as on any other treatments. These data suggested that movement of boll weevils in the area was random and those weevils collected simply blundered into the traps. The lack of success in trapping field weevils suggested that very few were present, however, it had been observed that the population of overwintered weevils in the field was extremely high. In this area very few weevils were trapped out of an extremely large field population, while the year before in the St. Joseph area a considerable number had been collected when field populations were known to be low. The response in the St. Joseph area indicated that boll weevils were possibly seeking mates upon emerging from hibernation sites, while at Clinton, in older cotton, no response was noted probably because the over-wintered weevils had been in the field long enough to have already mated.

The data obtained from the St. Joseph area later in 1966 further suggests that boll weevils respond to a sex attractant only when field populations are numerically low and mates are not readily available. In this test numerous weevils were trapped, but an equal number on control traps indicated that boll weevils were not responding to caged weevils, but blundered into the traps during random movement about the field. As seen in Table XVI, there was no significant difference in numbers of weevils collected from five trap treatments during 1966.

The lack of numbers of weevils collected in addition to variation observed, does not allow conclusions to be made without further detailed studies.

SUMMARY

Overwintered boll weevils congregated in early planted border rows of cotton provided the difference in planting dates was sufficient to give a distinct difference in size of plants. Insecticides applied on areas of boll weevil concentration retarded buildup of boll weevil populations in adjacent areas, therefore, delaying the date at which overall insecticide treatment had to be initiated.

Where fields of red foliage cotton were bordered by narrow strips of green foliage cotton, boll weevils tended to congregate in the border strips upon their entering the fields. This concentration was thought to be due to the proximity of the border strips to hibernation sites as well as nonpreference for the red foliage selection. Where such congregation occurred, application of insecticides prevented movement into the remainder of the test and thus delayed boll weevil buildup in this area.

Behavior of the boll weevil in the field in response to the sex pheromone was studied. Significant response to caged weevils was obtained only during the early part of the cotton growing season at which time overwintering boll weevils were entering the cotton fields. This response indicated that both the boll weevil and the thurberia weevil emit some sort of sex attractant, or

assembling scent, to which boll weevils respond under certain conditions. Caged males were significantly more attractive to field weevils than were caged females, however, both sexes were attracted to the caged males.

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VITA

Julius Roscoe Bradley, Jr. was born at Minden, Louisiana on March 25, 1940. He attended primary and secondary school at St. Joseph, Louisiana. In May, 1958, he was graduated from Joseph Moore Davidson High School.

In September, 1958, he entered Louisiana Polytechnic Institute at Ruston, Louisiana. Requirements for a Bachelor of Science degree in Biology were met and the B. S. degree was conferred in May, 1962.

Bradley entered Louisiana State University as a graduate assistant in the Department of Entomology in September, 1962. On August 24, 1963, he married Carol Joan Sellers. He received the Master of Science degree in Entomology in May, 1964. At present he is a candidate for the degree of Doctor of Philosophy.

EXAMINATION AND THESIS REPORT

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Major Field: Entomology

Title of Thesis: Oriented Movement of the Boll Weevil in Response to Trap Crop Plantings, Foliage Color and Sex Pheromone

Approved:

Dan F. Clower

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Date of Examination:

March 20, 1967